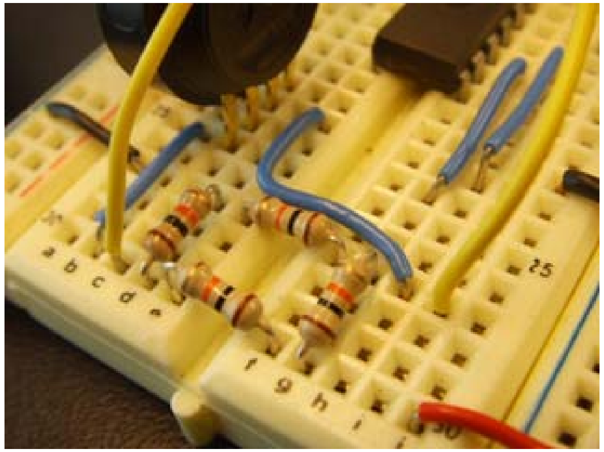
# Bridge Circuits

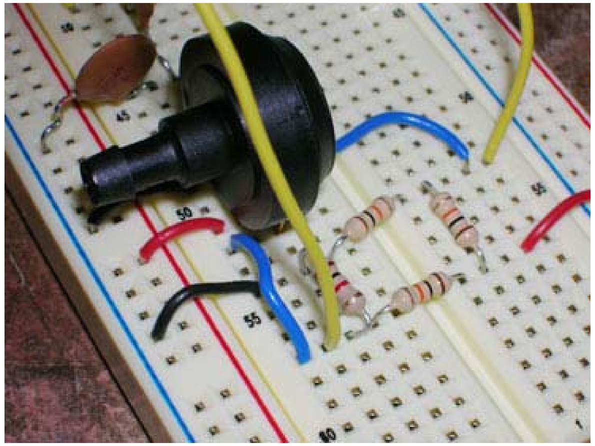
- Bridge circuits are used very commonly as a variable conversion element in measurement systems and **produce an output in the form of a voltage level** that changes as the measured physical quantity changes.

- They provide an accurate method of measuring resistance, inductance and capacitance values, and enable the detection of very small changes in these quantities.

- Many transducers measuring physical quantities have an output that is expressed as a change in resistance, inductance or capacitance.

# Null-Type, DC Bridge [Wheatstone Bridge] (1)






Sir Charles Wheatstone

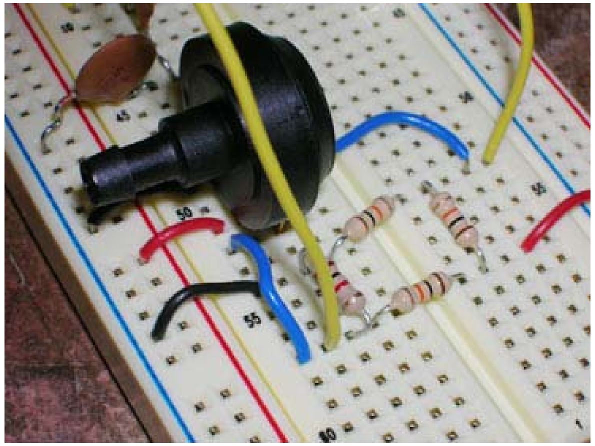
1802 - 1875

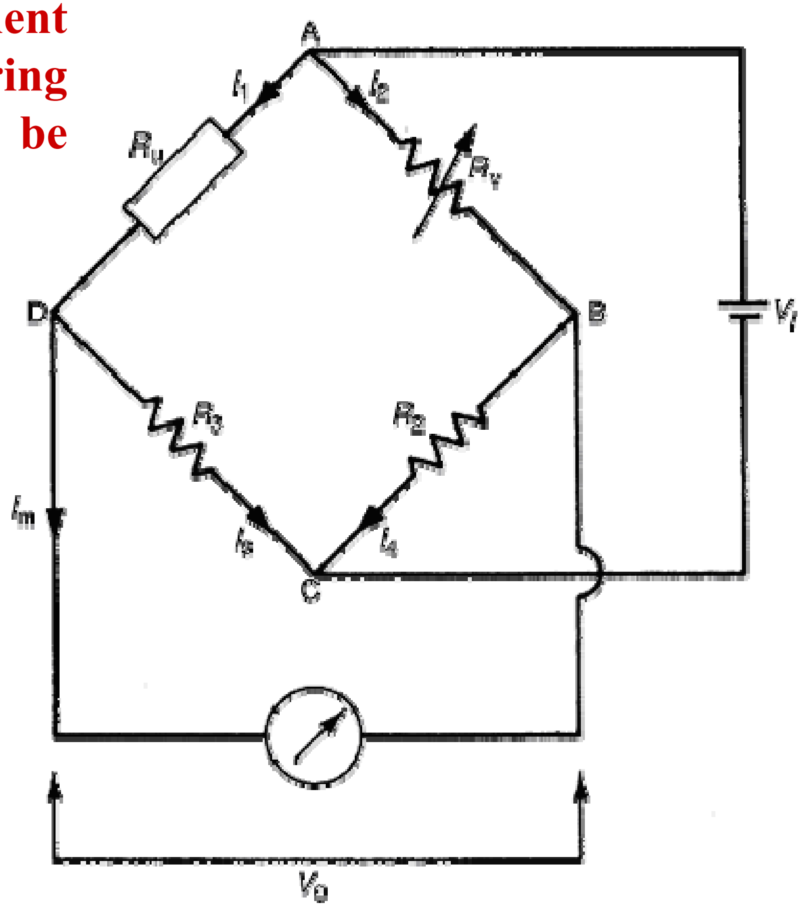
# Null-Type, DC Bridge [Wheatstone Bridge] (2)

If a high impedance voltage-measuring instrument is used, the current $I_m$ drawn by the measuring instrument will be very small and can be approximated to zero.

For $I_m = 0$

$I_1 = I_3$ and $I_2 = I_4$





# Null-Type, DC Bridge [Wheatstone Bridge] (3)

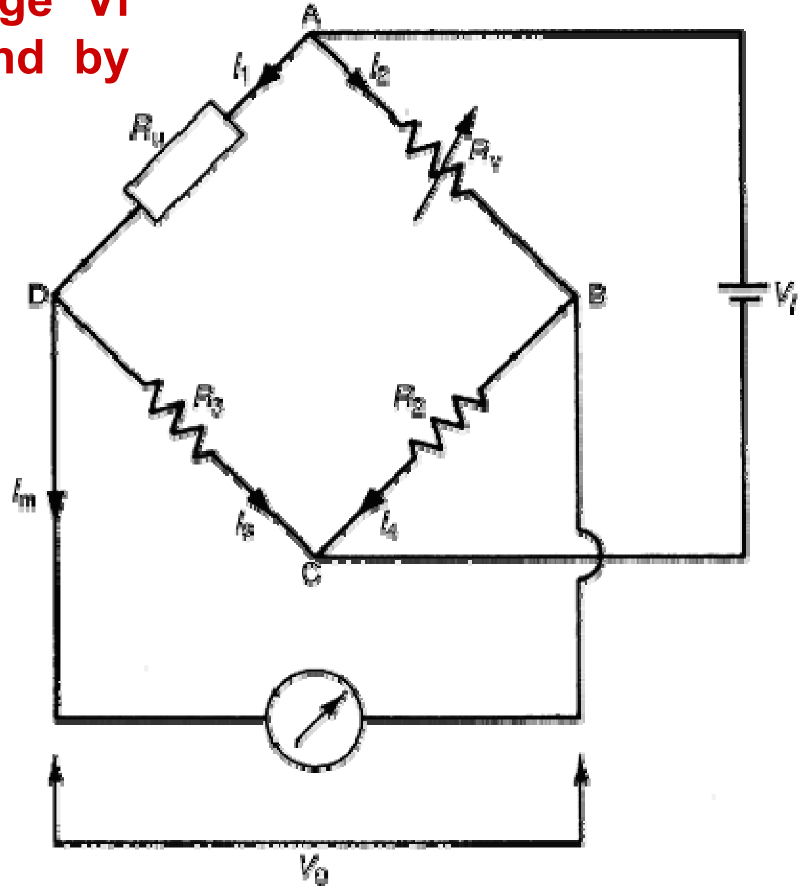
$I_1 = I_3$ and $I_2 = I_4$

Looking at path ADC, we have a voltage Vi applied across a resistance Ru + R3 and by Ohm's law

$$I_1 = \frac{V_i}{(R_u + R_3)}$$

Similarly for path ABC

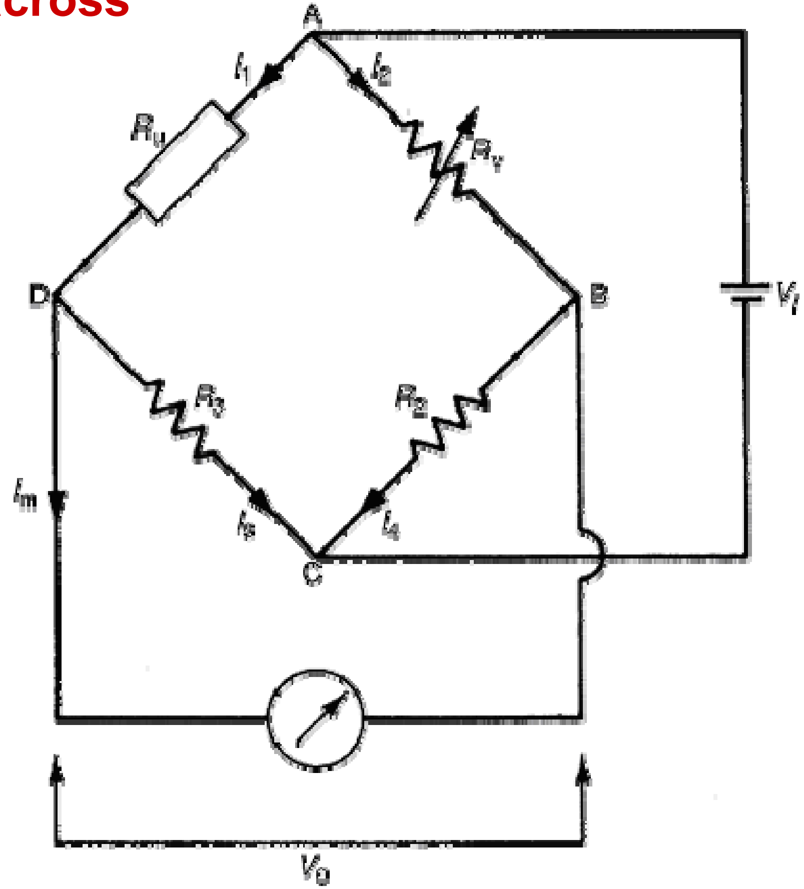
$$I_2 = \frac{V_i}{(R_v + R_2)}$$



# Null-Type, DC Bridge [Wheatstone Bridge] (4)

$I_1 = I_3$ and $I_2 = I_4$

**Now we can calculate the voltage drop across AD and AB**




$$V_{AD} = I_1 R_u = \frac{V_i R_u}{(R_u + R_3)}$$

$$V_{AB} = I_2 R_v = \frac{V_i R_v}{(R_v + R_2)}$$

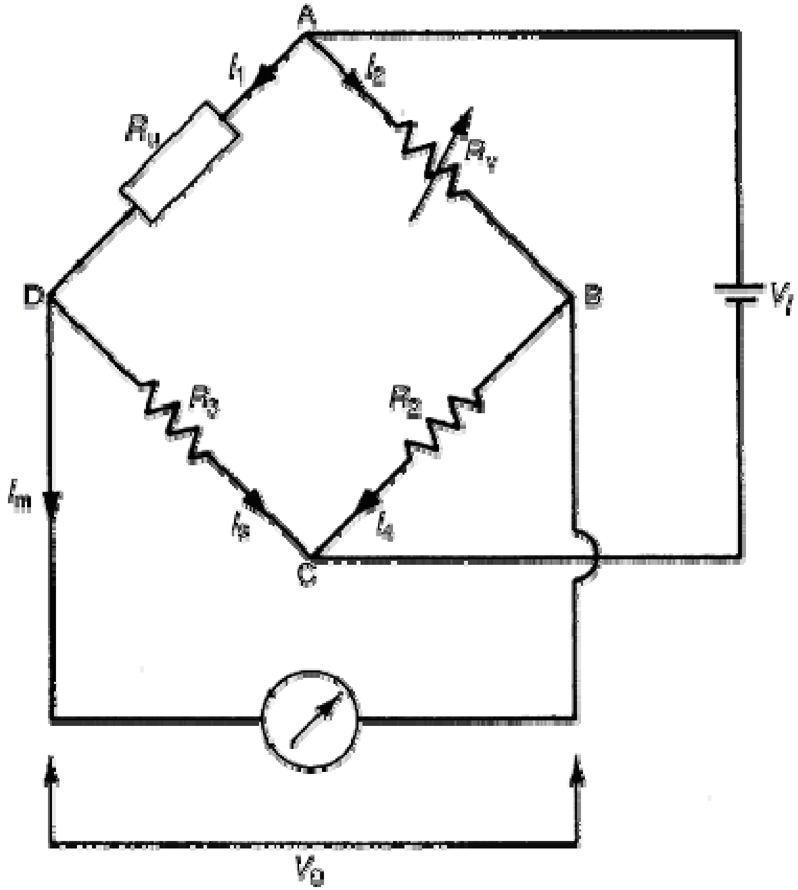
**By the principle of superposition**

$$V_o = V_{BD} = V_{BA} + V_{AD} = -V_{AB} + V_{AD}$$

# Null-Type, DC Bridge [Wheatstone Bridge] (5)

$V_o = V_{BD} = V_{BA} + V_{AD} = -V_{AB} + V_{AD}$

$I_1 = I_3$ and $I_2 = I_4$




Thus

$$V_0 = -\frac{V_i R_v}{(R_v + R_2)} + \frac{V_i R_u}{(R_u + R_3)}$$

At the null point $V_o = 0$, so

$$\frac{R_v}{(R_v + R_2)} = \frac{R_u}{(R_u + R_3)}$$

# Null-Type, DC Bridge [Wheatstone Bridge] (6)

**Inverting both sides**

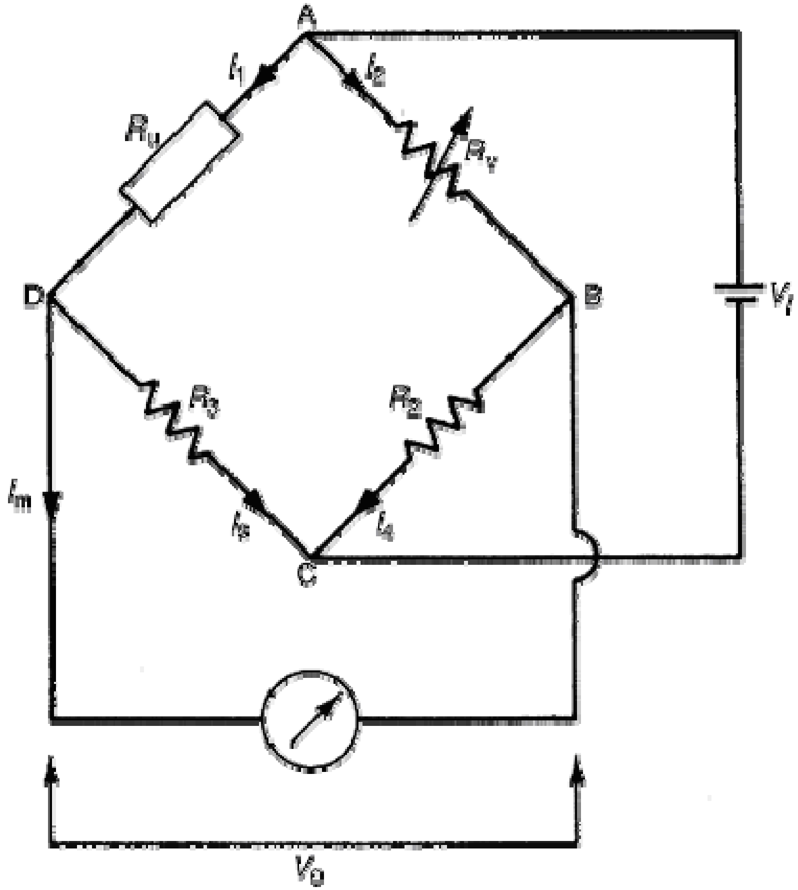
$$\frac{(R_v + R_2)}{R_v} = \frac{(R_u + R_3)}{R_u}$$

$$\text{i.e.} \quad \frac{R_3}{R_u} = \frac{R_2}{R_v}$$

$$\text{or} \quad R_u = \frac{R_3 R_v}{R_2}$$

**If $R_2 = R_3$, then $R_u = R_v$**

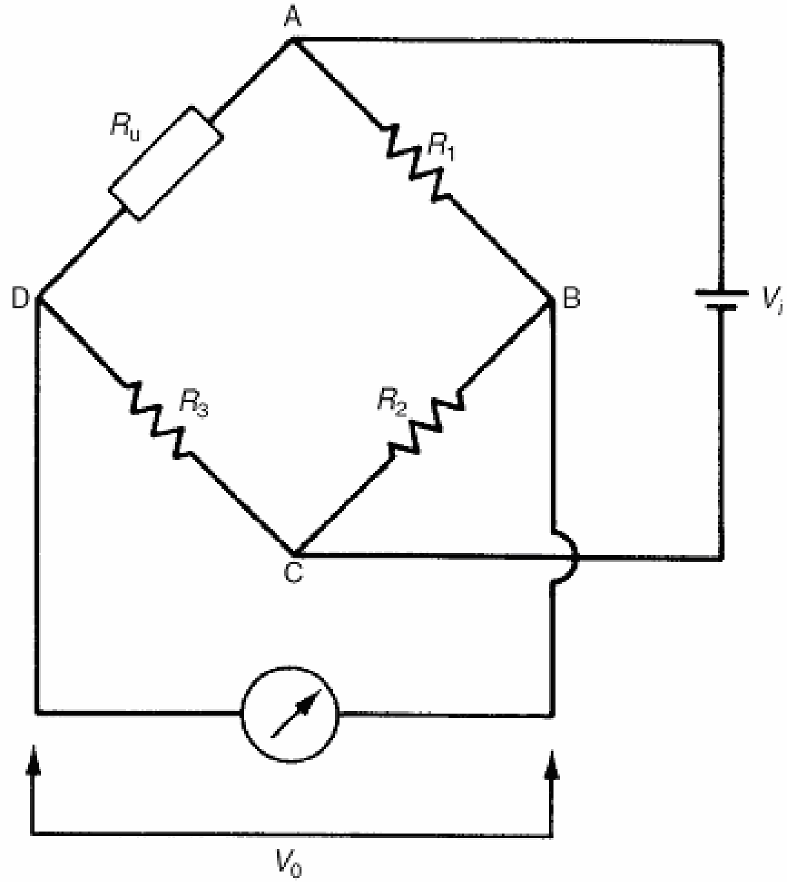
$I_1 = I_3$ and $I_2 = I_4$



# Deflection-Type DC Bridge

$$I_1 = I_3 \text{ and } I_2 = I_4$$

$$V_0 = V_i\left[\frac{R_u}{(R_u + R_3)} - \frac{R_1}{(R_1 + R_2)}\right]$$




**If $R_u = R_1$, then $V_o = 0$**

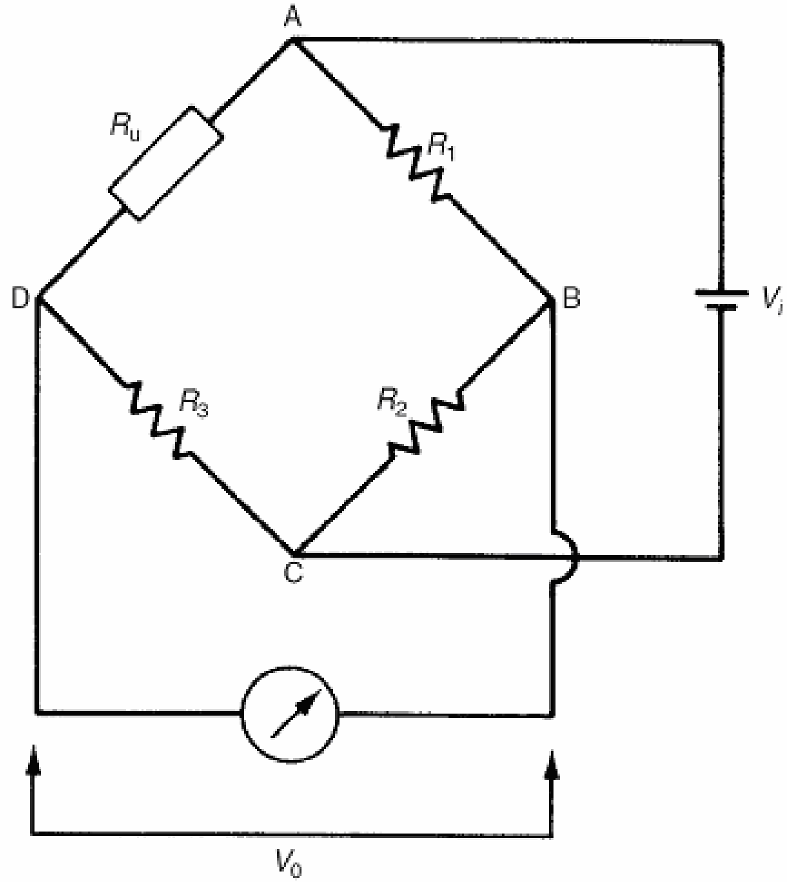
For other values of $R_u$, $V_0$ has negative and positive values that vary in a **non-linear way with $R_u$.**

# Example (1)

**Example: (page 161)**

$I_1 = I_3$ and $I_2 = I_4$

A certain type of pressure transducer, designed to measure pressures in the range 0–10 bar, consists of a diaphragm with a strain gauge cemented to it to detect diaphragm deflections. The strain gauge has a nominal resistance of 120Ω and forms one arm of a Wheatstone bridge circuit, with the other three arms each having a resistance of 120 Ω. The bridge output is measured by an instrument whose input impedance can be assumed infinite. If, in order to limit heating effects, the maximum permissible gauge current is 30 mA, calculate the maximum permissible bridge excitation voltage. If the sensitivity of the strain gauge is 338 mΩ /bar and the maximum bridge excitation voltage is used, calculate the bridge output voltage when measuring a pressure of 10 bar.



# Example (2)

$R_1 = R_2 = R_3 = 120\Omega$

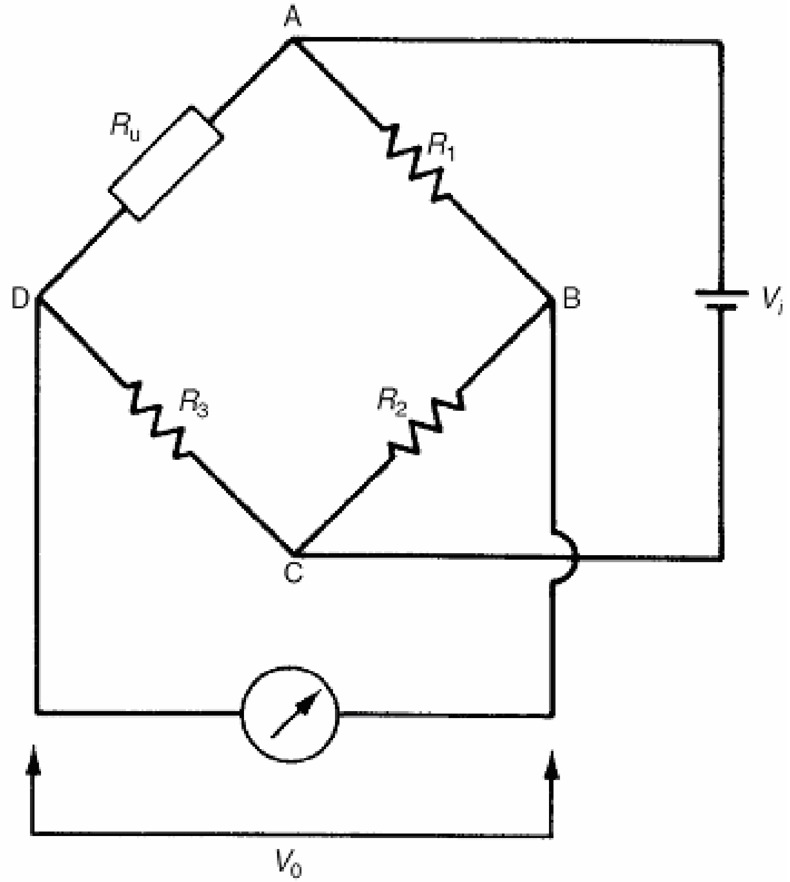
Defining $I_1$ to be the current flowing in path ADC of the bridge, we can write

$V_i = I_1 (R_u + R_3)$

At balance, $R_u = 120\ \Omega$ and the maximum value allowable for $I_1$ is 0.03 A. Hence

$V_i = 0.03\ (120 + 120) = 7.2\ V$

**Thus, the maximum bridge excitation voltage allowable is 7.2 volts.**



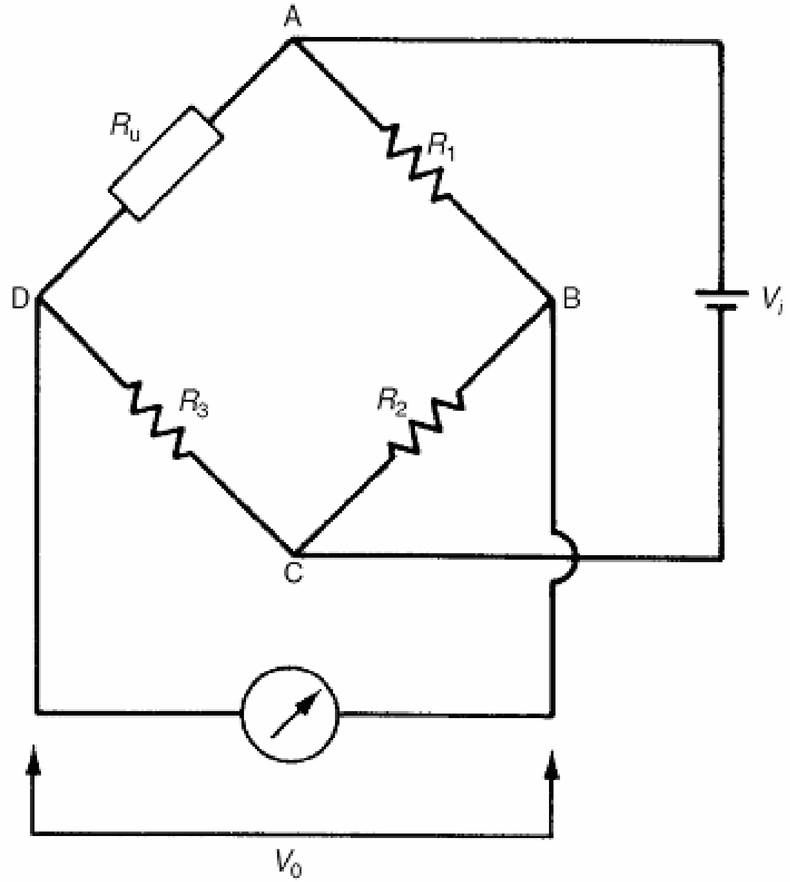
# Example (3)

**For a pressure of 10 bar applied, the resistance change is 3.38 Ω, i.e. $R_u$ is then equal to 123.38 Ω**

$$V_0 = V_i\left[\frac{R_u}{(R_u + R_3)} - \frac{R_1}{(R_1 + R_2)}\right]$$

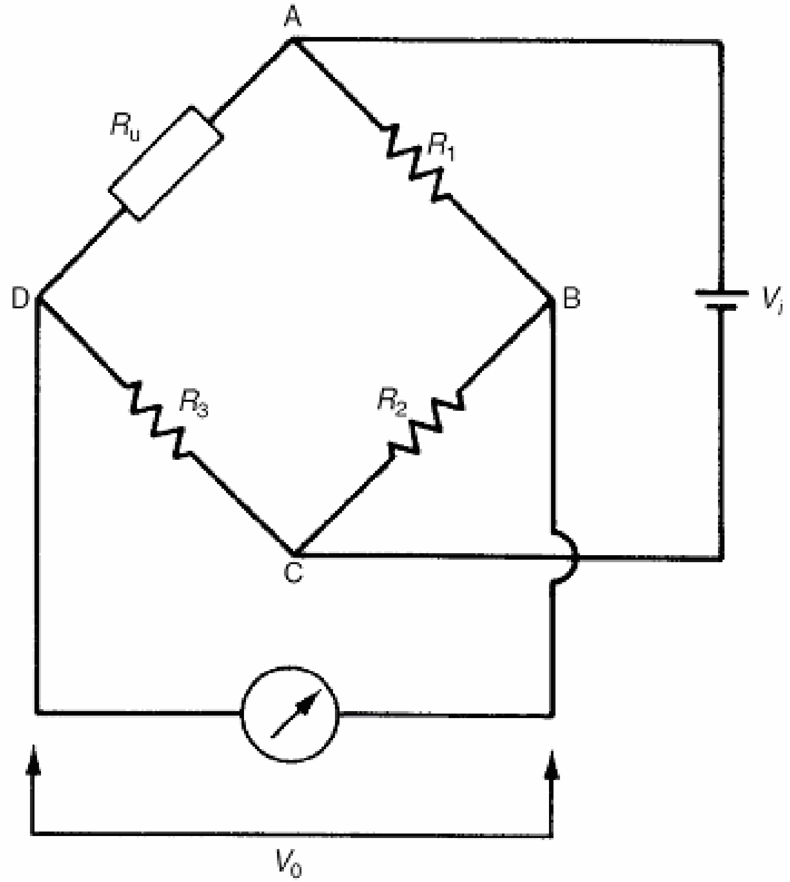
$$= 7.2\left[\frac{123.38}{243.38} - \frac{120}{240}\right] = 50\ \mathrm{mV}$$

**Thus, if the maximum permissible bridge excitation voltage is used, the output voltage is 50 mV when a pressure of 10 bar is measured.**



# Deflection-Type DC Bridge Non-Linearity (1)

$$V_0 = V_i\left[\frac{R_u}{(R_u + R_3)} - \frac{R_1}{(R_1 + R_2)}\right]$$



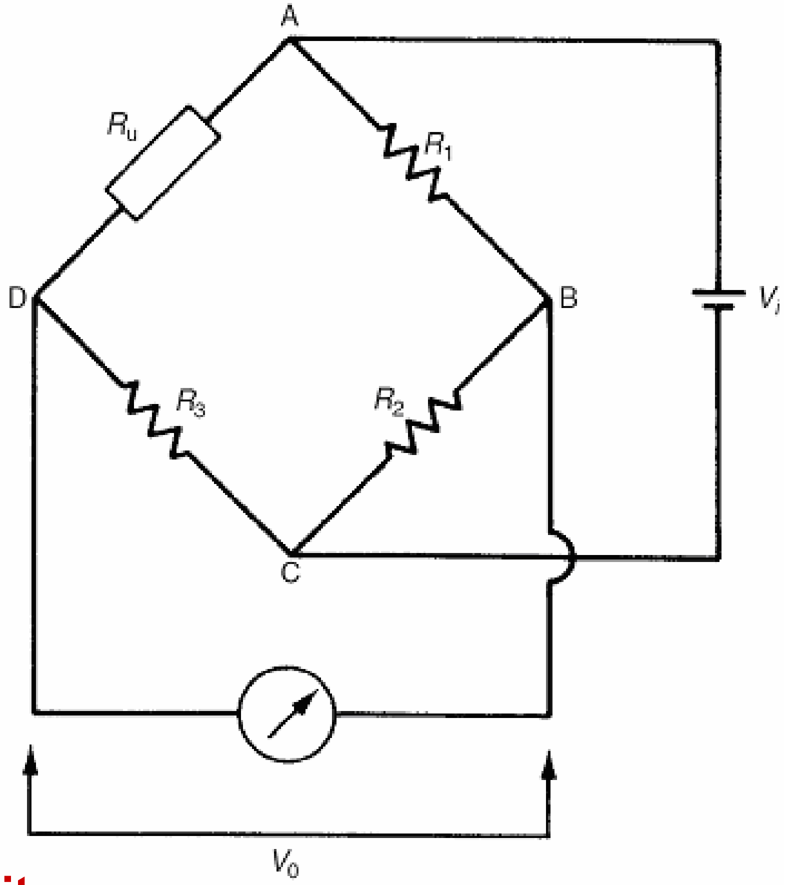

**The non-linear relationship between output reading and measured quantity exhibited by the above equation is inconvenient and does not conform with the normal requirement for a linear input–output relationship.**

**One special case is where the change in the unknown resistance $R_u$ is typically small compared with the nominal value of $R_u$.**

# Deflection-Type DC Bridge Non-Linearity (2)

The new voltage $V'_0$ when the resistance $R_u$ changes by an amount $\delta R_u$, is given by

$$V'_0 = V_i \left[ \frac{R_u + \delta R_u}{(R_u + \delta R_u + R_3)} - \frac{R_1}{(R_1 + R_2)} \right]$$




The change of voltage output is therefore given by

$$\delta V_0 = V'_0 - V_0 = \frac{V_i \, \delta R_u}{(R_u + \delta R_u + R_3)}$$

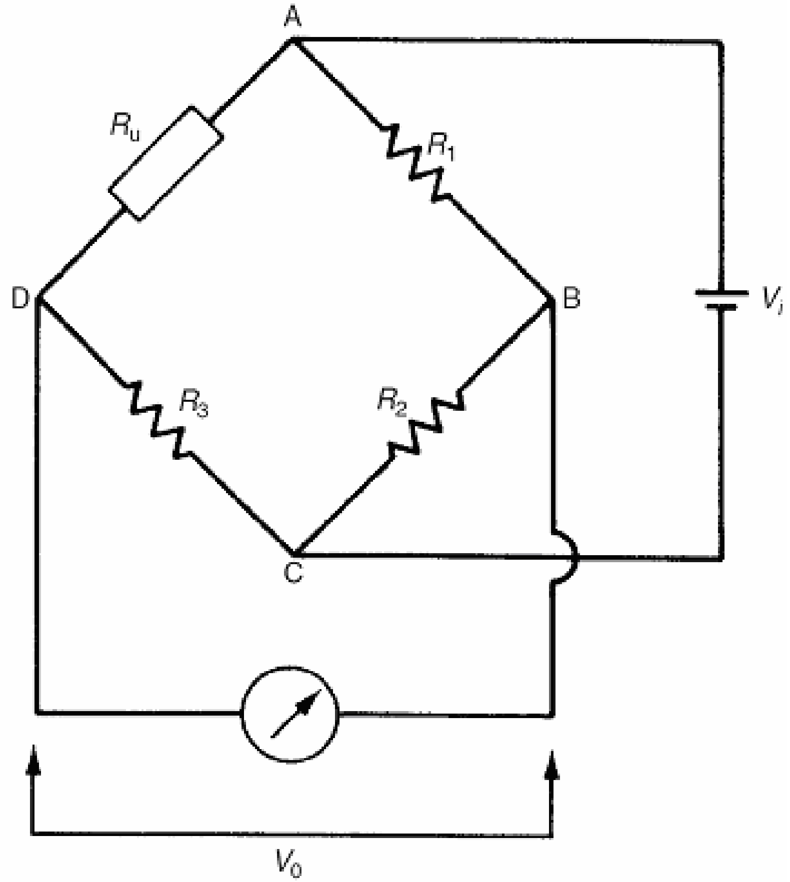
**If $\delta R_u \ll R_u$**, then the following linear relationship is obtained

$$\boxed{\frac{\delta V_0}{\delta R_u} = \frac{V_i}{(R_u + R_3)}}$$

**Bridge sensetivity**

# Deflection-Type DC Bridge Non-Linearity (3)

Consider a platinum resistance thermometer with a range of 0°–50°C, whose resistance at 0°C is 500 Ω and whose resistance varies with temperature at the rate of 4 Ω/°C. Over this range of measurement, the output characteristic of the thermometer itself is nearly perfectly linear. Taking first the case where R1 = R2 = R3 = 500 Ω and Vi = 10 V




At 0°C; $V_0 = 0$ V

At 25°C; $R_u = 600\Omega$ and $V_0 = 10\left(\frac{600}{1100} - \frac{500}{1000}\right) = 0.455\text{V}$

At 50°C; $R_u = 700\Omega$ and $V_0 = 10\left(\frac{700}{1200} - \frac{500}{1000}\right) = 0.833\text{V}$

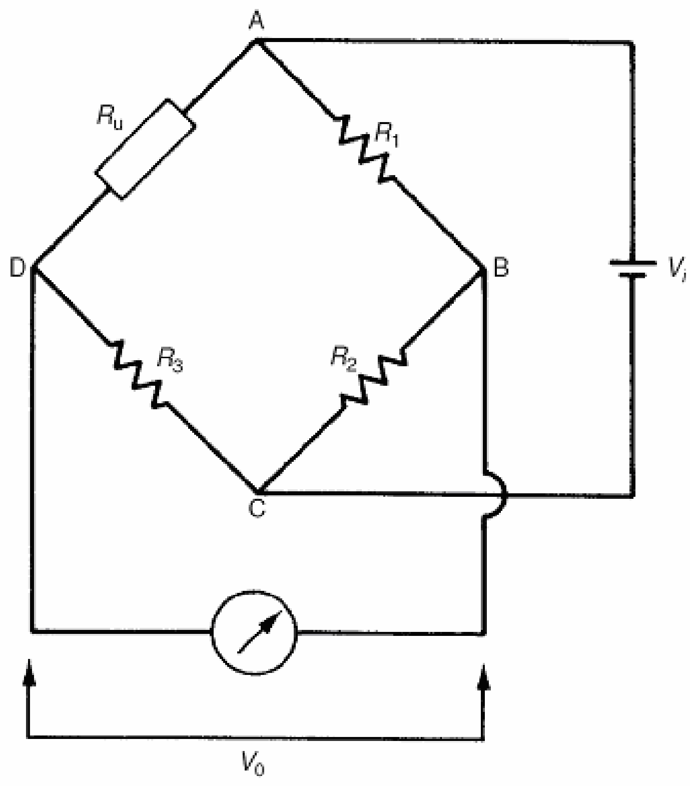
# Deflection-Type DC Bridge Non-Linearity (4)

**Now take the case where R1 = 500Ω but R2 = R3 = 5000 Ω and let Vi = 26.1 V**

$$\text{At } 0°\text{C; } V_0 = 0 \text{ V}$$

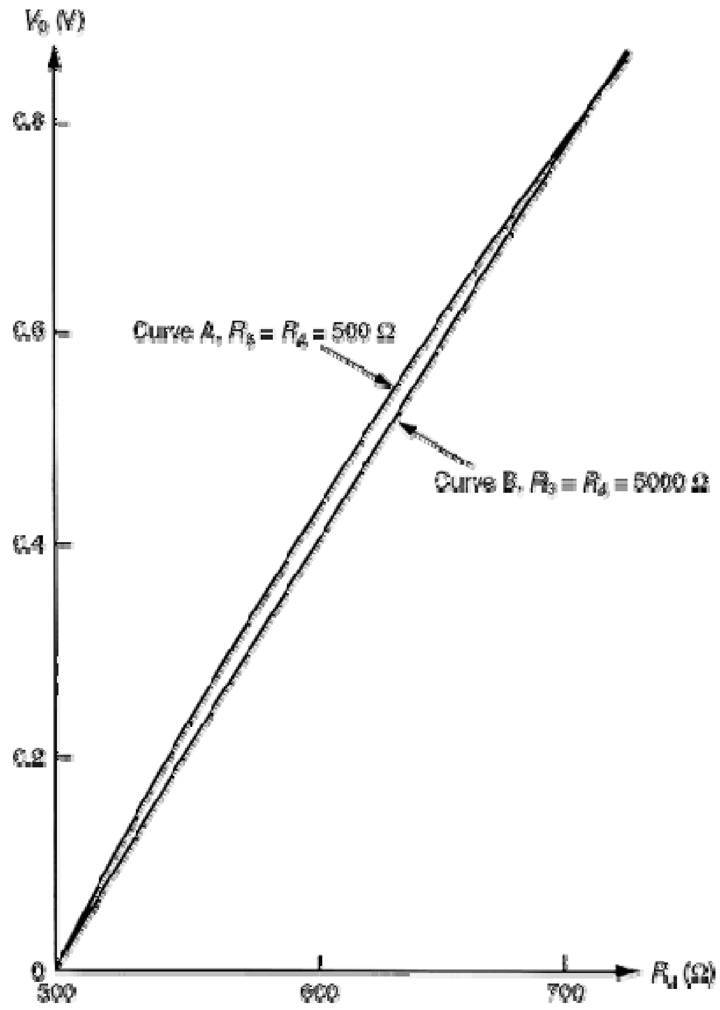
$$\text{At } 25°\text{C; } R_u = 600\Omega \quad \text{and} \quad V_0 = 26.1\left(\frac{600}{5600} - \frac{500}{5500}\right) = 0.424\text{V}$$

$$\text{At } 50°\text{C; } R_u = 700\Omega \quad \text{and} \quad V_0 = 26.1\left(\frac{700}{5700} - \frac{500}{5500}\right) = 0.833\text{V}$$



# Deflection-Type DC Bridge Non-Linearity (5)

- Increasing $R_2$ and $R_4$ reduces non-linearity of the circuit output.
- However, Vi must be increased to maintaine the same output level.
- Circuit heating must be avoided.




Thank You!